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EDITORIAL

ANIMAL HUSBANDRY IN THE COLONIES

An Empire can be judged by the way in which its colonial affairs are managed and by the loyalty of the colonists. Good management leads to prosperity, and prosperity enhances good relationships and a closer binding of those familiar ties which are so essential to the well-being of both parent and offspring.

The British Empire has a proud record and can justly claim to be the most successful and united Empire that this world has seen. This is all the more remarkable, for the Empire is made up of a heterogeneous collection of races which are widely scattered over the globe. If one seeks an explanation for this happy state of affairs the answer is a simple one; it is, that in the course of development, whilst still retaining the ancient title, the relationship between the parent and offspring has changed from one of domination to that of commonwealth. No matter what has been the political sentiments of those in power at the centre the guiding spirit of all contact, almost from the very inception, has been "the parent exists for the help and guidance and not the exploitation of the offspring."

Under such circumstances it is not surprising that there has grown a sentiment of mutual confidence and deep attachment between peoples of great diversity of race and language and outlook. The ties between us are the strongest that could be forged, for they are based not solely upon legal enactment but upon the true family spirit or code. One for all and all for one. That this is the right spirit there is no doubt, for twice within the last thirty years the Colonies have come to the succour of the Motherland and given of their all. It would be untrue to assume that we have done all that should have been done for the Colonies in the past, but it can be said that the Mother Country has always endeavoured to perform her parental duties to the best of her ability, according to the prevailing circumstances. Now our Colonies are basically agricultural communities. It is true that in the process of time other

industries have arisen, but in the main these are offshoots of agriculture or in other words have been grafted on the basic factor and on which they depend for raw materials. It follows therefore that the well-being of a Colony depends in its widest sense upon the state of its agricultural industry. Now agriculture as practised in the British Commonwealth shows a great diversity in range, but one section is common to all, no matter what the site or environment, namely, Animal Husbandry in all its branches. Good animal husbandry is the very "king pin" of agriculture, and it is in this realm that the veterinary surgeon can render his greatest service to the community. Many of our *Colonies* were in the first instance, and indeed still are, pastoral areas. The wealth of the country was reflected in the size and quality and health of its herds.

In the past the members of the Colonial veterinary service have done a wonderful job, and under great difficulties. In many cases they have been first in the field, and their work has not only paid dividends in stock improvement but also in wider spheres, for they have developed and fostered those feelings of sentiment and confidence which are so essential when dealing with primitive people. Past evidence therefore shows that the veterinary surgeon has been a great and successful coloniser, and it is good to note that this is now fully recognised by those in authority. Recently the need to develop animal husbandry in the West Indies has been recognised by grants made under the Colonial Development and Welfare Act of 1940. A free grant of £1,200 has been made for the purpose of making a survey of animal husbandry conditions throughout the area. One of our colleagues, Prof. W. C. Miller, of the Royal Veterinary College, has been appointed to carry out the work and he is now in the West Indies. The questions of diseases amongst stock in the Colony has given rise for some concern, and it is hoped that the survey will facilitate advances in the field of research and stock breeding.

Another grant which will benefit stock farmers in the West Indies is one for £3,800 for the establishment of a State Veterinary Service in St. Kitts Nevis.

We wish Prof. Miller every success in the work he has undertaken and, judging this incident as an augury for the future, we hope that the time will not be long delayed when other Colonies may look forward to similar help in their problems and that members of the veterinary profession will be able to render great service to the Empire and be recognised by those in authority as the only competent authority in what is undoubtedly their own sphere.

General Articles

STUDY OF THE ARTERIAL AND LYMPHATIC SYSTEMS IN THE UDDER OF THE COW*—I

By M. A. A. M. EL HAGRI, B.Sc.(Edin.), D.V.S.M., M.R.C.V.S.,
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In recent years many research workers have directed a great deal of their efforts to expand previous knowledge on the various aspects of the morbid conditions affecting the udder of the cow. The problem, however, still remains and occupies universal attention equal to the magnitude of the economic losses sustained in the past and which are still not in abeyance at the present.

It is generally accepted that the majority of the pathological changes of the udder are attributable to bacterial infection reaching this organ, either via the blood or lymph streams. Therefore it is of importance to have at our disposal a fair knowledge of the anatomical relation of these systems in the udder before any satisfactory explanation of the possible course and dissemination of an infection of this organ can be attained.

This study was made for the object of obtaining further information on the anatomical distribution of the lymphatics of the udder and the relation that might exist between them. In addition, special attention was given to the study of the various modes of the lymph drainage of either side of the organ, before and after leaving it.

Material and Methods

Work was conducted on udders which were collected from both destroyed and dead cows at the knackery at Loanhead. Udders obtained at an early state of putrefaction were still suitable for injection. In these the flow of the injection material through the lymph vessels was facilitated by the liberation of a certain amount of putrefactive gases which seemed, as it were, to distend the lymph spaces or what may be described as the physiological connection between the tissues and the lymph capillaries. Owing to war-time restrictions, radically diseased udders could only be obtained from the slaughter-houses. Such udders were subjected to routine meat inspection examination, which resulted in the destruction of the existing connection between the lymph nodes and their associated lymph vessels. Under these circumstances, it was practically impossible to secure a closed system for a successful injection. These udders, however, were useful for studying the various modes of the flow of the lymph either among the lymph nodes of either side or between the group of lymph nodes of both sides. In all, 42 udders were collected and studied for this work.

The method found suitable for this purpose is based on the modification of Gerota's method as described by Jamieson and Dobson (1910). The pressure apparatus used was in principle the same, but, for convenience in dealing with the udder, a newly-devised tube was added, which was referred to as the injection tube (Fig. 1). This consisted of a wide-mouthed tube about 2½ inches in diameter fitted with a rubber stopper and connected to the bottle containing the injection material. The flow of the latter could be regulated by a clip on the rubber

* Thesis presented for the Fellowship Diploma of the Royal College of Veterinary Surgeons.

connection. The other end of the tube was dilated to form a hemispherical bulb about 5 in. in diameter, provided at its base with a number of finger-like exits, each exit being fitted with a separate pressure tubing of a suitable length, to which a clip was attached. The other ends of these rubber connections were fitted with fine hypodermic needles. The whole injection tube, with its fittings, was fitted on a clamp on which it could be raised or lowered as required. This modification was found to have the following advantages:—

(1) Both hands were left free for manipulation of the specimen, such as massaging while being injected, or adjusting the pressure whenever required.

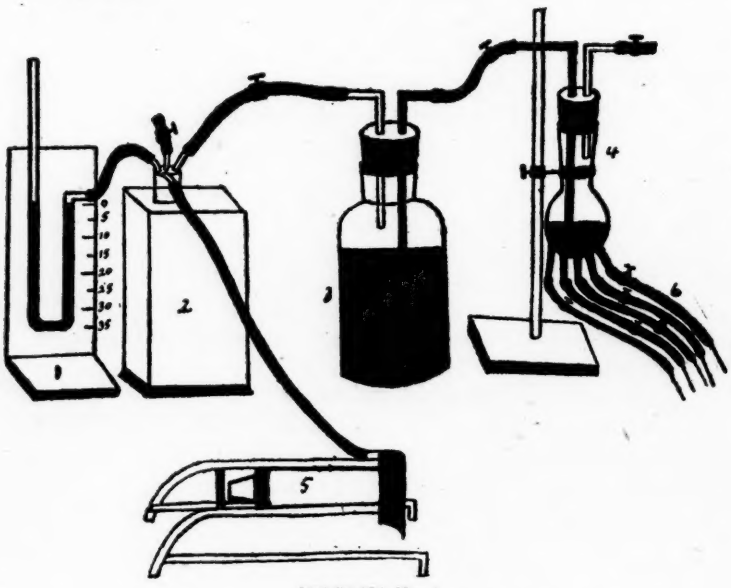

DIAGRAM No. 1.
The apparatus used for injecting the lymphatics of the udder.
1. Mercury manometer.
2. Pressure case.
3. Bottle containing injection material.
4. Injection tube.
5. Foot pump.
6. Rubber connections fitted with hypodermic needles.

(2) All lymph vessels could be injected in a single operation.

(3) Various ranges of pressure could be used for injecting the various lymph vessels of the udder without interrupting the whole process. For instance, if all lymph vessels were to be injected at one time, a low pressure of 100-150 mm. of Hg., which was suitable for injecting the deep lymph vessels, was first applied. Under this pressure, however, the superficial lymph vessels were also injected, though not to the required extent. When the process was completed, the flow of the injection material to the parenchyma was stopped by clipping the corresponding connections from the injection tube. At the same time the pressure was then raised to the required level to complete the adequate injection of the superficial lymph vessels.

(4) The blockage of the hypodermic needles, which often occurred during the process, could be detected by noting any change in the rate of the flow of the injection material into the injection tube.

(5) Economy both in time and material against unnecessary wastage was attained.

Fresh udders were found preferable for injection, although not essential. Organs in a state of rigor mortis, or an advanced condition of putrefaction, were avoided for obvious reasons. Artist oil colour of ultramarine blue was used instead of prussian blue. This substitution was made for the merits of ultramarine blue in showing the fine radicles of the lymph vessels and of having no tendency to infiltrate into the surrounding tissue and mask the whole preparation.

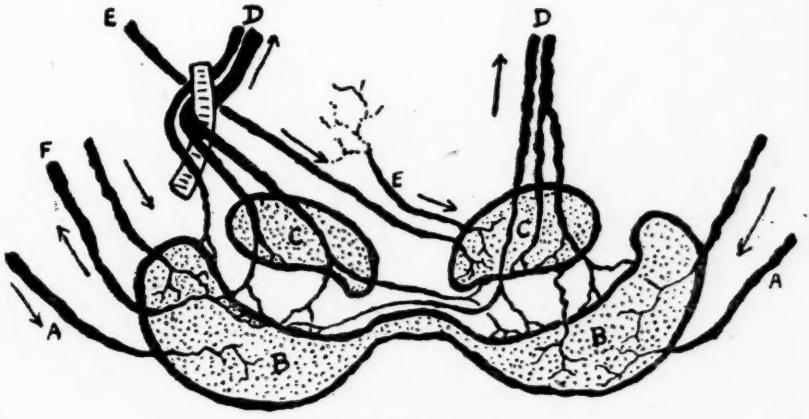

DIAGRAM No. 2.

Showing connection of superficial supramammary lymph nodes and reciprocal type of lymph drainage.

A. Superficial afferent lymph trunks.
B. Superficial supra-mammary lymph nodes.
C. Deep supra-mammary lymph nodes.
D. Main efferent lymph trunks.
E. Lymph vessels crossing to the right side.
F. Independent efferent lymph vessels, possibly to pre-femoral lymph node.

The superficial or subcutaneous lymph vessels were injected by introducing the hypodermic needles at various points under the skin and the submucosa of the nipples. A pressure of 300-450 mm. Hg. was used. The completion of the process was judged by the fact that the course of the superficial lymph trunks was rendered visible while the skin of the organ was still intact.

The deep lymph vessels were injected by introducing the hypodermic needles deep into the parenchyma at several points. A pressure of 100-150 mm. of Hg. was used. Several attempts had to be made before any satisfactory results could be obtained. For the cutaneous lymph vessels, the injection was made at several points into the deeper layer of the skin or dermis, especially on the ventral surface of the organ and in the neighbourhood of the nipples.

During the whole process, the udder was situated on its base, a position which favoured the flow of the injection material towards the lymph nodes. The injected specimens were then left for 1-2 hours in the same position to allow

enough time for the fine lymph vessels to fill before they were preserved in 10 per cent. formalin.

Results and Discussion

The Lymph Nodes of the Udder

Baum (1927) described the lymph nodes of the udder as a group of 2-7 nodes, usually two only were present, situated between the ventral wall of the pelvis and the caudal part of the base of the udder, under the skin. The largest of these he called the supra-mammary lymph node; the smaller nodes might be

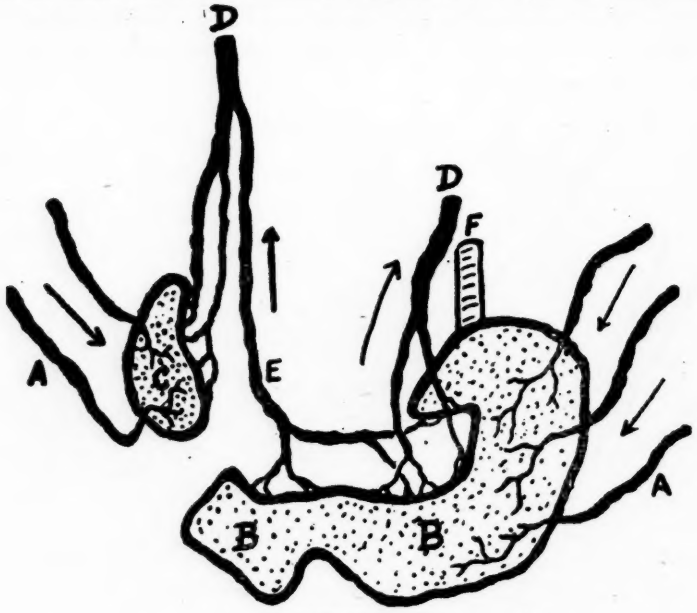

DIAGRAM No. 3.

Showing fusion of superficial supra-mammary lymph nodes and unilateral type of lymph drainage.

A. Superficial afferent lymph vessels.
B. Superficial supra-mammary lymph nodes.
C. Left deep supra-mammary lymph nodes.
D. Main efferent lymph trunks.
E. Efferent lymph vessel crossing to the left side.
F. Right mammary artery.

absent on either or both sides of the organ. When the latter nodes were present, they varied in number—usually two only were present. He pointed out that the accessory lymph node or nodes were present only in horses and cattle, and that they were found in about half of the cases in adult cattle. However, Baum did not give either a clear statement regarding the position of what he described as the accessory or accessories, or on what grounds these were distinguishable from the other lymph nodes. Ellenberger and Baum (1932) described the position of the accessories in the horse but did not refer to them in cattle. Zietschmann (1917) described the usual presence of two lymph nodes, on either side, one being large, flattened, and superficial in position; the other small, thick, and deep in position. Sisson (1941) stated that, in the cow, usually two lymph glands were present on either side. The larger were in opposition

medially and were sometimes united. The smaller glands were above or in front of the larger ones. Exceptionally, a third gland might be present, or there might be only one on one side.

The results obtained in this respect revealed that the maximum number of lymph nodes encountered on either side was four nodes in any of the specimens examined, these being situated on the caudal third of the base of the udder in close relation to the mammary vessels under the fascial investment of the organ. The largest of these varied considerably in size, and presented a crescentic or kidney-shaped appearance. The remaining lymph nodes varied in

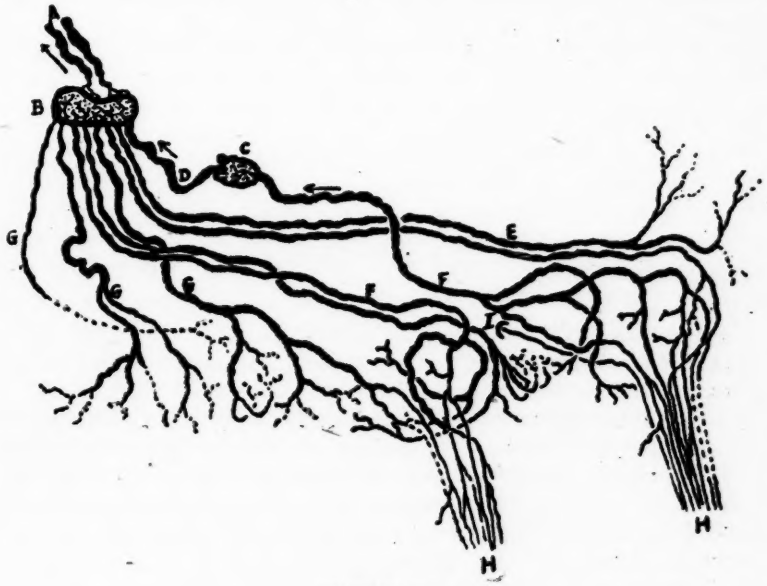

DIAGRAM No. 4.

Showing the accessory lymph node, lymph vessels of superficial parenchyma and nipples (Right side).

A. Main efferent lymph trunks.
B. Superficial supra-mammary lymph node.
C. Accessory lymph node.
D. Efferent lymph vessel of accessory lymph node.
E. Superficial parenchymal lymph vessel.
F. Lymph vessels of nipples.
G. Superficial parenchymal lymph vessels of posterior quarter.
H. Lymphatic plexus of nipple.
I. Lymph vessel from nipple entering deep parenchyma.

number from one to three and were situated either closely in front of the largest lymph node (supra-mammary of Baum) or deep to it, the latter position being more frequently encountered. In two of the specimens examined, one of these nodes was situated at a distance of 4-6 in. cranial to the mammary vessels and 1-2 in. from the lateral border of the base of the organ. In all the specimens examined, the superficial supra-mammary lymph node was present on either side. The deep supra-mammary lymph node or nodes, however, were present in 24 specimens only, i.e., in 57.1 per cent. of all the cases. Of these, 19 specimens showed the deep lymph nodes on either side, and in the remaining five specimens these nodes were present only on the left side. In four other specimens only, representing 9.5 per cent. of all cases examined, 1-2 lymph nodes

were situated on the lateral surface of the organ. In three of these specimens, one lymph node only was present at a distance of 3-5 in. cranial to the supra-mammary lymph node and 1-2 in. ventral to the lateral border of the base of the udder. In the remaining specimen, two lymph nodes were present; one was situated as in the previous cases and the other, 2-3 in. immediately below or ventral to the supra-mammary lymph node. In every case these latter nodes intercepted the path of part of the lymph carried by some of the superficial lymph vessels before it reached the supra-mammary lymph node. Although the previous statement gave a general account of the lymph nodes of the udder, it was considered convenient to report at length on the observations carried out regarding these lymph nodes.

The lymph nodes of the udder may be described in two main groups, as follows :—

1. Superficial Group .

This comprises the supra-mammary and accessory or accessories of Baum. In order to distinguish the supra-mammary lymph node from the other members of the deep group which are similarly situated on the base of the udder, it is convenient to describe the supra-mammary lymph node as the superficial supra-mammary lymph node in accordance with its superficial position and its mainly receiving the superficial lymph vessels.

(a) The Superficial Supra-mammary Lymph Node

This lymph node represented the largest and main lymph node of the organ. Its presence was constant and, in relation to the mammary vessels, caudal. In two specimens, the lymph nodes of both sides were connected by a narrow isthmus of lymphoid tissue across the median plane. In one specimen only, the two lymph nodes were fused together to form one single mass of lymphoid tissue (Figs. 2 and 3). The superficial supra-mammary lymph node received all the lymph drainage carried by the lymph trunks of the nipples, the superficial parenchyma, and the skin. In addition, it received all the lymph leaving the node or nodes encountered on the lateral surface of the udder, when these were present. On the other hand, the lymph from the deep group of lymph nodes either entered it or proceeded independently, as will be described at a later stage.

(b) The Accessory or Accessories

It has already been stated that one or two lymph nodes were found in 9.5 per cent. of the specimens, occupying a position on the lateral surface of the udder and situated on the course of some of the superficial lymph vessels draining into the superficial supra-mammary lymph node (Fig. 4). In accordance with their primary function of receiving lymph from the same areas draining into the superficial supra-mammary lymph node, the term accessory or accessories should be applied to these lymph nodes, to distinguish them from other lymph nodes of the organ. The accessory lymph node was connected with the superficial supra-mammary lymph node by one efferent lymph vessel. Where the accessory lymph node was situated cranially, it was embedded in a certain amount of fat which concealed its position. In the other situation, where it was found immediately below the superficial supra-mammary lymph node, it was on a level with the lateral surface, occupying a depression in the parenchyma.

2. Deep Group

The deep supra-mammary group was composed of a number of lymph nodes much smaller in size than the superficial supra-mammary lymph node. These nodes varied in size from ½ to 1 in. in diameter, and presented an oval or rounded appearance. In the majority of the specimens examined where these lymph nodes were present, usually one lymph node, not infrequently two, and very occasionally three, were found on either side. Usually this group was found in relation to the mammary vessels cranially in either a superficial or deep position to the superficial supra-mammary lymph node, the latter position being most common. However, one of these lymph nodes may be found at a distance of 4-6 in. cranial to the mammary vessels and 1-2 in. from the lateral border of the base of the organ, as already mentioned; this lymph node should not be confused with the accessory lymph node found more or less at similar distances, but on the lateral surface of the udder. The distinction between these two lymph nodes lay in the fact that while the lymph node belonging to the deep group received afferent lymph vessels from the deep parenchyma of the base of the udder, the accessory lymph node received afferent superficial lymph vessels. In two specimens, there was fusion between one of the nodes of the deep supra-mammary group and the superficial supra-mammary lymph node. In well-fed subjects, the supra-mammary groups of lymph nodes were covered by a large amount of fat, while in lean animals fat was either scanty or entirely absent.

(*To be continued*)

THE STUDY OF ANIMAL BEHAVIOUR FROM THE VETERINARY ASPECT: OR, THE IMPORTANCE OF PROSECUTING THE STUDY OF ANIMAL BEHAVIOUR, AND SUGGESTIONS FOR ITS DEVELOPMENT AS A FIELD OF VETERINARY ENDEAVOUR—II

By J. T. EDWARDS, D.Sc., M.R.C.V.S.,

(Concluded)

(4) ". . . In the future I see open fields for far more important researches. Psychology will be securely based on the foundation already well laid by Mr. Herbert Spencer, that of the necessary acquirement of each mental power and capacity by gradation. Much light will be thrown on the origin of man and his history. . . ."—CHARLES DARWIN (1859), *The Origin of Species* (concluding chapter).

(5) ". . . The third method by which it has been attempted to attack the problems of psychology is that which I have called comparative. Its characteristic note is a distrust of that attitude towards phenomena which I have called the human point of view. Man's description and interpretation of his own mental experience being so liable to distortion by prejudice, by self-esteem, by his views as to his own nature and powers, as well as so incomplete by reason of his incapacity to reach by ordinary introspection the deeper strata of the mind, it becomes necessary to make action as far as possible the subject of observation rather than speech, and to regard it as a touchstone of motive more important than the actor's own views."—WILFRED TROTTER (1916), "Instincts of the Herd in Peace and War."

(6) ". . . Of all the branches of learning which make up the science of zoology, that of animal psychology appears to me to be the highest. Anyone who has worked through all the various departments of zoology, through the study of various animal forms, through morphology, embryology, theory of descent, comparative physiology, and all the rest of the many branches, should, I think, find at last in animal psychology the most important teaching of all, and one of particular value as regards a deeper view of man and his place in Nature. . . ."—F. ALVERDES (1932), "The Psychology of Animals in Relation to Human Psychology" (Kegan Paul).

(4) The Present Veterinary Outlook

It is not always easy to impress upon modern veterinary workers the real meaning and importance of animal behaviour as a study, and it is probably hardest of all to impress it upon my own friends and contemporaries, whose minds have become conditioned through long habit in prosecuting some ancillary technological branch of study.

It may be permissible to draw upon a much wider field of human thought for analogy. One could say with justice that the great factor in Western civilisation, namely, Greek culture, though it wrought great and lasting good towards humanity, did untold harm in its efforts to elevate the human personality by its deliberate shunning of the comparative method, and thereby did nearly as much to provoke the Dark Ages as to redeem them. In the same way it might well be said that the greatest beneficent influence wrought on modern medicine, namely, the Pasteurian doctrine, in its efforts to establish the truth concerning the nature of infectious processes, has done untold harm by relegating the animal itself, as it were, to the status of a laboratory reagent.

Much depends upon the interpretation one places on the word "veterinary." Of low Latin origin, *veterina*, having reference it seems to draught animals too old* to be used for other purposes, the word *veterinarius* appears to have been used in Rome as a coarse attribution to animal attendants, the term preferred for the more dignified healers of animal diseases being *medicus*, qualified by the name of the species, hence *mulomedicus, medicus equorum* (used as late as the 13th century), *medicus pecorum*, etc. It then became introduced, almost reluctantly, having to suffer competition with names (marshal, farrier, hippiatrist) which were sometimes held in higher esteem, in the Western European languages in the course of the 17th and 18th centuries. The word first appeared in English as "veterinarian" in a book written in 1646 by Sir Thomas Browne (the author of *Religio medici*). John Hunter also spoke of "veterinarian"; Sainbel, the Frenchman appointed as first head of the London College in 1791, spoke of "veterinary physician." It was a Board of General Officers sitting in 1796 who decided upon referring to the recruits from the London College enlisted to attend upon sick animals as "veterinary surgeons," to distinguish them from the Army surgeons who were already employed for attending upon the human personnel and who had often lent their hands to the treatment of animals. This term soon became applied to the civil profession and was the legal designation in the Charter of Incorporation of 1844 and the Veterinary Surgeons Act of 1881. It is, of course, as Sir Fred Smith has said, a misnomer; for members of the

* The words "veterinary," "veteran" and "wether" (sheep) have a common etymological association with the meaning "old" (*vetus, veteris*).

profession have always been more physician than surgeon. Neither are the terms employed in languages which have a designation manufactured from the native language really appropriate: the Germanic word *Tierarzt* does not cover the whole field of the veterinarian's endeavours, for he is not only a healer or doctor but takes as well within his field of competence all matters concerning the hygiene and breeding of animals; *Tierkunde* has therefore been claimed to be the more appropriate name for the field of work. As it is, the term *veterinarian,* with its comprehensive and remote etymology, fittingly designates the wide variety of vocational aspects in which the bearer of this name is employed, comprising as these do at the present day the three main ones of clinical practice, preventive medicine and animal husbandry. As far back as 1828, the founder (William Percivall) of the journal which long served the profession as its premier mouthpiece in this country, decided on the title "The Veterinarian." No slur need be inferred from the common abbreviation of this title by the public, for it has also come to mean in common speech the submission of the object of a transaction to a competent and trustworthy examination.

The claim therefore that the study of animal behaviour ought not to find place within the narrow confines of a veterinary surgeon's duties cannot be entertained, for the original meaning of the word "veterinary" is sufficiently embracing to include all that concerns the economy of the domesticated animals, in health as well as in disease. No one who wishes to apply himself to any of the problems concerned with animal welfare need hesitate to qualify himself for the legal designation "veterinary" on account of any apprehensions entertained regarding its narrowness, for in truth many workers who are engaged upon the problems of animal breeding and nutrition are more "veterinary" in the etymological sense than some of the legally qualified men, who have found an outlet for their energies in some of the ancillary technologies, such as bacteriology.

To continue: until McFadyean, after several years at anatomy, introduced, almost with a vengeance, pathology and bacteriology into veterinary teaching in the late 1880's, and these were incorporated as a separate subject for examination when the R.C.V.S. curriculum was extended from three to four years in 1895, there was not much that was worthy of the name of veterinary "science" as apart from the veterinary "art" taught at the British veterinary schools.

The question arises whether in default of all this newer "scientific" teaching, almost boundlessly expanded, and embracing several other sciences which have also rightly since then come to be regarded as needful, the old-time veterinary graduate did not possess something in his mental equipment which has never found the soil wherein to germinate in the mind of the newer graduate, choked out as that something has been by a medley of technicalities which have obscured from his vision the animal itself as an intelligent being.

Something was done, most wisely, by the framers of the R.C.V.S. curriculum when it was extended in 1895 by insisting upon the inclusion of stable management in the earlier part of the training, and thus imparting to it a vocational flavour throughout. This subject was redesignated animal management when the course was extended to five years in 1932. Ought the intention of those men who stressed the inclusion of this subject, crude as it may seem to the more advanced technologist, be further implemented by raising it to a still higher

status as a truly vocational discipline in as early a part of the training as possible?*

Medical educationists have been no less concerned with tendencies similar to our own. The old type of family physician, it has been deplored, is fast disappearing. No longer are the centres of training filled with a fair sprinkling of young men who in childhood had a bent towards natural history, betrayed by a natural urge for an outlet to their early enthusiasms, such as collecting beetles, moths, birds' eggs, etc. On the contrary, a prolonged preclinical training in the objective sciences has, it has been stressed, the defect of keeping the student with no strong natural aptitude towards the study of the living too long away from his true life-work. He finds real difficulty in reconciling his early training with what he finds when he arrives at, and then deems to be merely empirical, the later or vocational part of the training. For this reason, elementary psychology has recently come to be included as a subject in the preclinical part of the training, and the importance of this inclusion has been stressed in the recent Goodenough Report on Medical Education. Recommendations are also made, it will be remembered, to bridge over the parts by including in the early portion of the clinical part a more rational explanation of general principles of clinical art.

(5) The General Importance of the Study of Animal Behaviour

Before taking up the study of animal behaviour from any particular aspect, such as the veterinary aspect, it is necessary to take a general view of the subject by looking at it from different aspects. Indeed, one is led almost inevitably into contemplation of the subject from the viewpoint of its wider implications whenever one attempts to elucidate any single behaviour phenomenon in any given species. I need only mention three or four of these different—sometimes diverging and sometimes converging—aspects :—

(a) *The Natural History Aspect.*—An immense literature is now accumulating on this aspect emerging from the recorded observations of diverse workers such as entomologists, ornithologists, etc. This is all extremely useful and salutary, for it makes one realise that the field covered by studies on the domesticated animals is a relatively small one and in many ways a highly artificial one.

(b) *The Psychological Aspect.*—The immense progress made by what has come to be called the psycho-analytical school of psychologists has caused the adherents of this school to expand and extend their interests to the comparative domain, drawing, for example, on the successive stages in insect development to find analogy with transitions occurring from birth to maturity in the human psyche. A standard text-book, in its preface, even goes so far as to say that

* The implications of this question could not be more aptly expressed than in the summary published since the above was written of the remarks of one of the speakers during the Discussion on Comparative Psychology and Animal Behaviour at the last session of the Comparative Section of the Royal Society of Medicine (*Proc. Roy. Soc. Med.*, 1944, *37*, 661) :—

"*Dr. John Hammond* said that the papers that afternoon had opened a very promising field for investigations on farm animals. A thorough study of animal behaviour would not only be useful to veterinarians in making diagnoses—for they had a much more difficult job than the doctor, whose patient can tell him what he feels and what he wants—but it also formed a scientific basic for what we knew as animal management. A good stockman by keen observation knew what an animal wanted and saw that it got it: studies such as Prof. Johnstone-Wallace had made showed promise of resolving this art of animal management into a science and so enabling great progress to be made in animal health and productivity. He hoped that more studies would be made on these lines, particularly in sheep which were dependent on grazing to an even greater extent than cattle."

until human psychology had widened its foundation so as to embrace the whole animal kingdom it had come almost to a full halt for want of good evidential material that was subject to discriminating study.

(c) *The Didactic Aspect.*—This is very seldom stressed. If, for example, one were to endeavour to explain fairly to a class of students the meaning of a problem like sterility and how it has arisen prominently in domestic cattle only during the last half-century, one would first have to point to the fact that this species led a semi-feral existence until less than two hundred years ago and that since then the processes of natural evolution had been strained to produce an animal capable of providing, for human needs, a secretion immeasurably in excess of what the species needed for its natural perpetuation. The strain would cause certain aberrations in several of the body systems, notably the endocrine glands, the autonomic nervous system, and the involuntary musculature (bringing in its train faulty involution of the reproductive tract). The upset to the autonomic nervous system would further cause, in a manner the detail of which could be presented, syndromes affecting other systems than the reproductive tract, such as milk fever, lactation tetany, etc. Further discourse on diseases of this order would bring it to bear upon a host of familiar conditions, such as pregnancy toxæmia in ewes, swayback in lambs, canine hysteria, until one had traversed right through the provinces traditionally allocated to the neurologist, psychiatrist and psychologist, and one emerged finally from contemplation of so much that was "abnormal" into an almost melancholy realisation of the need there had always been, but somehow had been overlooked, to study the "normal." That is to say, through a devious process of continuing to direct attention towards the "abnormal" one would be brought back to a vision of the "normal." This, as we know, is not a new thing in medicine. As the writers of a standard English text-book on bacteriology (Topley and Wilson) say in a profound statement delineating the history of their subject, which for long was studied as an "applied" science before it began to be studied as a "pure" science: "It is almost true to say that the clue to the present position of bacteriology is the curious fact that there have been no bacteriologists." It would perhaps be an exaggeration to say, for a somewhat similar reason, that there have been no psychologists!

(d) *The Economic Aspect.*—It would be idle now to pretend that the old-time breeder, with all the wonders he is granted to have achieved, accomplished something which a well-versed modern geneticist—using all the resources which his science has already put within his grasp and still more so with the resources that are almost certain to be made available to him in a not-distant future—could not do as well and probably far better. What is happening around at the present day shows how rapidly technological processes can be exploited in emergency. Similarly, the old-time "empiric" can surely be outdone in the matter of animal "knowledgeability" when rational study of animal behaviour has been taken up in earnest.

I need only instance three recent studies as examples:—

(i) The work of Stapledon and his assistants on grazing behaviour in sheep. This has shown, among other things, that the sheep naturally does not soil with its excreta the richest grazings but has sufficient intelligence to deposit them on the poorest. Hence until recently the teachings of the orthodox helminthologists were wrong.

(ii) The studies of Johnstone-Wallace on the grazing habits of beef cattle are of immense interest. They show in a way that is striking that when the natural habits of these cattle are fully understood and the management of the pastures adjusted to fit in with these habits, cattle can be nourished and fattened far more economically on good grassland than by the arithmetically calculated systems of indoor rationing devised by animal nutritionists within the last few decades.

(iii) The observations of Walton on artificial insemination. The interest of these observations extends well beyond, it is understood, the immediate economic problem, most important though that is known to be. By throwing light on the delicacy of the adjustments which determine potency in the bovine male they are, we are assured, of immense potential significance in explaining personality problems arising from sexual maladjustment.

(6) Steps Suggested for Prosecuting Work on Animal Behaviour as a Veterinary Discipline

As was soon realised in the course of talks with my colleague, Professor Dalling, with the object of presenting a programme for acceptance by proper authority, it is not easy to offer suggestions that can be assured of permanent success. A false step at the beginning might vitiate development for an untold time to come. Money is not the only consideration. The most difficult thing at the present time is to find the men who could be trusted to do the pioneering, even if money and posts were forthcoming. Certainly there is a great deal of material available at the existing research institutes which could well be exploited. The use that could be made of the material at the larger institutes by a trained animal behaviourist is very great, and provided he was of the right communicative temperament his value to the other members of the staff would be immense. This applies to institutes dealing with research into the various problems of animal husbandry and agronomy as well as to the veterinary research institutes. Doubtless an individual with a natural bent for the study would be found to carve his way here and there whenever circumstances were propitious, and he would, no doubt too, do good and useful work. The foundation of research professorships at some of the universities, as recently at Aberystwyth, is of singularly good omen. Such foundations have been in existence in some countries, particularly in Germany, for a long time. A strong bias at certain of these towards the prosecution of studies which comprised prominently those of animal behaviour would depend upon the inclinations of the professor, and if he took up this field as his life-work he would assuredly bequeath a valuable legacy to the future by apprenticing young assistants in his methods. It is not to be thought possible, or even desirable, that each such professorship would become the nucleus of a complete veterinary teaching centre. The multiplicity of specialist workers required to man properly a complete veterinary teaching centre has become so great that the resources of the country would be sorely taxed to provide many centres that were staffed and equipped in a manner that could be regarded as complete. It is worthy of some note that the authors of the recent Goodenough Report on Medical Education set their face against the creation of teaching centres additional to the twenty already in existence—this to provide for a total profession of something over sixty thousand members. *Pari passu*, the veterinary profession with a little over three thousand members

ought to be content with a single centre. The circumstances in regard to the accessibility of clinical material and several other things are, however, so different that a fair and just comparison cannot be made, so that at any rate a plea for two good centres on the same model could be justifiably set up, related, for administrative purposes, probably best to the large universities. At such centres, among the numerous necessary constituent "units," there would be little danger that the inviting outlet represented by animal behaviour would be neglected.

Looking far ahead at the present time, the wisest plan on which to build seems to be to devise some system, such as would be presented by the elevation of the Animal Management of the present curriculum from its minor status to the major one represented by the wider discipline of Animal Behaviour as connoted by the examples already given in this paper. Transition from what has been arbitrarily called the "preclinical" to the "clinical" stages, which have not usually been well demarcated in veterinary curricula, would thereby become smoother, for insistence upon developing capacity for observation of the living animal would be made throughout the course.

The subjects of anatomy, physiology and animal behaviour would therefore rank as the major preclinical subjects. These could each be magnified, to denote their wide range, into comparative anatomy, comparative physiology and comparative psychology. As Leclaniche has, however, stressed, it is easy to overstress the comparative aspect of such studies, implanting on them thereby an excessively intellectual meaning and depriving them of the objectivity proper to sound vocational training. These major subjects would rest upon a foundation of more elementary scientific studies, the nature and variety of which it is unnecessary to repeat.

A few young men have already displayed remarkable perspicacity in recognising the outlet as here presented, and it seems well worth the risk to entrust them with the expansion of veterinary endeavour in the manner that now cries out to us. The system outlined, it is believed, through their efforts, will in time produce the exceptionally gifted few who will be competent to undertake further teaching and research, and at the same time communicate the discipline of animal behaviour to all who are turned out from our teaching centres with a professed knowledge of the animal economy.

Thereby, it is hoped that as the Pasteurian doctrine largely redeemed the veterinary art in some ways from sheer empiricism, expansion through this inviting outlet will save what gained for its practitioners their place in the confidence of the public and guard for them that reputation which privileges them as a profession. To lose this opportunity may well herald its break-up into an incoherent medley of technologies, and its justification to retain them those privileges no longer remain valid.

VARIATION IN SOME PHYSIOLOGICAL ACTIVITIES OF DAIRY COWS—II

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(*Concluded*)

The heart rates of all cows increased considerably during the latter part of pregnancy, the increase being most noticeable from the 12th week before calving. Although the respiration rates were higher at calving time, the increase

TABLE 5

The effect of pregnancy on the heart rate per minute, rectal temperature in °F. and respiration rate per minute of the four cows

	Weeks before calving															*Weeks after calving*		
Cow	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	1	2	3
Lily 7	63.3	64.8	68.5	64.0	64.0	64.8	65.2	67.7	69.8	71.3	70.7	72.1	79.6	80.8	77.2	70.2	60.3	64.0
Truth	63.2	65.2	67.2	66.2	69.0	69.8	73.6	71.6	73.9	77.8	78.9	16.9	77.2	76.3	75.4	69.5	65.0	64.0
Campion 11	63.0	59.0	59.7	61.3	65.2	69.7	67.7	67.0	69.9	68.1	74.5	72.3	78.7	80.8	83.2	75.8	65.4	68.7
Welcome 9	61.0	60.8	60.4	57.8	61.5	62.9	66.6	69.9	70.8	69.9	72.2	75.2	82.5	82.7	89.1	67.0	64.7	66.8
Mean heart rate ...	62.6	62.5	64.0	62.3	64.9	66.8	68.3	69.1	71.1	71.7	74.1	74.1	79.5	80.2	81.2	70.6	63.9	65.9
Mean respiration rate ...	29.4	28.1	27.7	25.1	26.6	26.7	28.9	25.5	26.2	25.1	28.3	28.8	32.0	29.7	30.3	26.1	26.0	23.1
Mean body temperature	101.46	101.33	101.13	101.32	101.50	101.34	101.46	101.34	101.47	101.26	101.50	101.73	101.90	102.25	102.47	101.84	101.39	101.50

TABLE 6

Mean increases in heart rate per minute, respiration rate per minute and body temperature in °F. from the 12th-15th week before calving to the two weeks before calving

	Heart Rate			Respiration Rate			Temperature		*Mean daily milk yield in lb. in first 10 weeks of lactation*
Cow	*Initial*	*Beats Increase*	*% Increase*	*Initial*	*Increase*	*% Increase*	*Initial*	*Increase*	
Lily 7 ...	65.2	15.0	23.0	25.3	5.6	22.1	101.94	0.81	40.1
Truth ...	65.5	10.4	15.9	25.4	3.9	15.4	101.26	1.14	26.7
Campion 11 ..	60.8	21.2	14.9	23.3	7.9	33.9	101.21	0.86	33.8
Welcome 9 ...	60.2	25.7	42.7	30.9	—0.4	—1.3	101.46	0.75	42.0
Mean ...	—	18.8	29.1	—	4.25	17.8	—	0.89	

was not of any regular nature. The increase in body temperature was only apparent following the 6th week before calving. After calving, heart rates dropped very rapidly, and were approximately basal by the second week. The large drop in the first few days after calving coincided with the time during which the cows were given little food but bran mashes—the routine practice in this herd. The mean increases in heart rate, respiration rate and body temperature for the individual cows are given in Table 6.

The individual increases in heart rate and respiration rate were variable, but there was a broad agreement between the relative increases in the heart rate and the respiration rate, with the exception of cow Welcome 9. Her respiration rate was very high during the 12th-15th week before calving (see Figure 2), and no noticeable change associated with pregnancy was noted for this cow.

TABLE 7
Observations throughout the pregnancy of cow Lily 7 in 4-week periods

Months pregnant	*Aug.* *1*	*Sept.* *2*	*Oct.* *3*	*Nov.* *4*	*Dec.* *5*	*Jan.* *6*	*Feb.* *7*	*Mar.* *8*	*Early April* *9*	*Late April and early May* *0*
Mean heart rate ...	50.9	53.8	63.5	61.1	60.9	64.9	64.4	69.9	77.4	64.8
Mean respiration rate	26.6	26.7	28.5	29.1	26.6	25.4	25.1	25.4	30.4	27.8
Mean temperature, degs. F.	101.4	101.3	101.4	101.3	101.6	101.5	101.6	101.7	102.4	102.0
Mean daily milk yield (lb.)	19.9	15.2	11.1	9.7	3.6	—	—	—	—	41.4
Mean daily food intake —lb. starch equivalent	11.6*	13.2*	11.6*	8.8	9.2	6.7	7.1	6.9	7.9	12.8*
Mean cowshed temperature, degs. F. ...	57.2	53.4	50.6	47.0	40.7	43.4	43.6	39.5	46.9	48.6

* Includes an estimate of pasture value.

There was relatively little variation in the rise in body temperature, but it is of interest to note that cow Truth, which calved twin bull calves, showed the highest increase in temperature. There was no relationship between the magnitude of the individual increases and milk production in early lactation, but taking the autumn calvers and spring calvers separately, those which gave the most milk had shown the highest heart rates during late pregnancy.

To show the longer term changes in the heart rate, the cow Lily 7, which was not pregnant at the commencement of the observation period, has been used, and the relative information regarding her is shown in Table 7. Her long dry period was due to difficulties in getting her in calf.

Table 7 is difficult to interpret owing to changing feeding and climatic conditions during the 10-month period. Besides the rapid terminal rise in the heart rate, it could be concluded that there is a rapid increase of 9.7 beats in the heart rate from the 2nd to the 3rd month of pregnancy. The low values in August and September, however, were associated with very poor pasture, and high environmental temperatures. Thus the remaining three cows had mean heart rates of 68.2 in June, when the pasture was good, and rates of 58.9 in August, when drought had reduced its feeding value. This was despite the fact that all three were one to four months pregnant at the time of the first measurement. It can be concluded therefore that it is improbable that there is any change in the heart rate in the first few months following service which is the result of pregnancy.

The high heart rates which gave the frequency distributions their char-

acteristic skewness (see Table 2) was largely due to the presence of high rates during the last two months of pregnancy. Thus the frequency distribution of the heart rate of a non-pregnant cow, taken over a period of three winter months

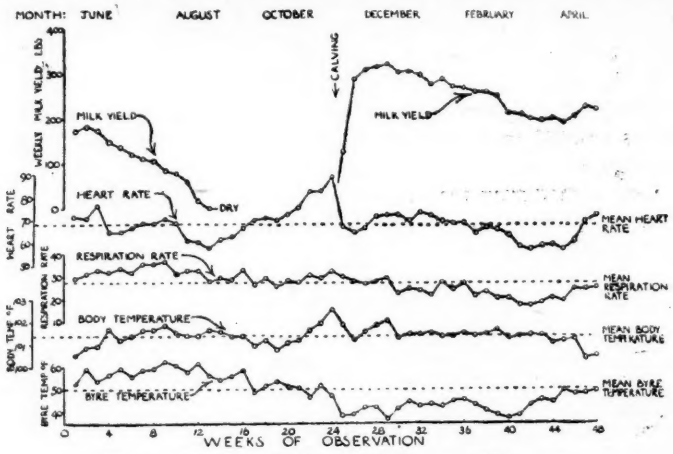

FIG. 2.—Complete clinical record for cow Welcome 9.

when she was fed a constant ration, showed that it was of a normal type, 68 per cent. of the morning and 60 per cent. of the evening records falling within a range of five beats.

The heart rates of the calves which were born were also taken. During the first week of life they were difficult to determine accurately, all being between

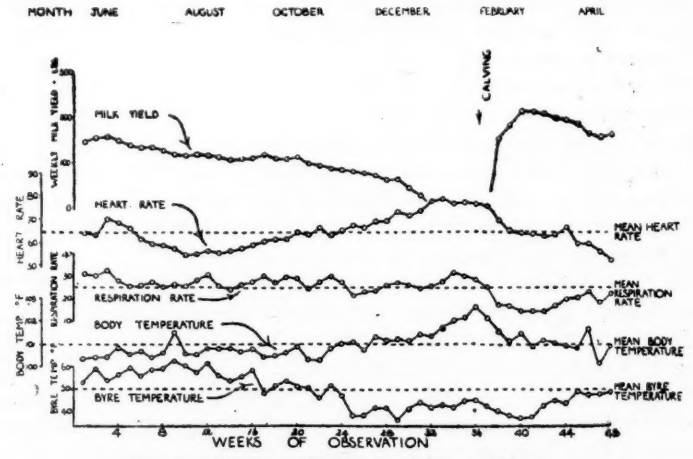

FIG. 3.—Complete clinical record for cow Truth.

140 and 200 beats per minute. Observations could not be continued on these calves, as they were sold for veal, but the high heart rates are obviously related to the high basal metabolism of the young calf as reported by Ritzman and Colovos (1943).

(c) *The effect of lactation.* The mean weekly data for cows Welcome 9

and Truth plotted in Figures 2 and 3 show both the heart rates and milk yield during lactation, and it will be seen that there is a relation between them for increases in heart rate tend to be associated with increases in milk production. This relationship has also been noticed by Ralston Cowsert *et al.* (1940). Over long periods, the relationship is not direct, for it can be seen that besides the association of milk yield with the heart rate there is a general decline of milk

TABLE 8

Relationship between resting heart rate and the deviations of milk yield from the mean fall of milk yield with time

Cow	*Weeks of lactation studied*	*No. of weekly records*	*Heart rate range*	*Mean weekly fall of milk yield in lb.*	*Correlation "r" between the heart rate and deviations from mean fall of milk yield*	*Increase in weekly milk yield per one beat increase in resting heart rate*
Welcome 9	3-26	24	72.8-57.5	—5.5	+0.734	+2.59
Campion 11	3-22	20	68.8-57.7	—6.3	+0.762	+2.61

yield regardless of the level of the heart rate. During short periods, however, the normal decline in the lactation cannot often be discerned. To measure the correlation between the heart rate and milk production the data has therefore been treated in two parts, one direct, the other indirect. The correlation between two variables when one shows a progressive change with time presents many

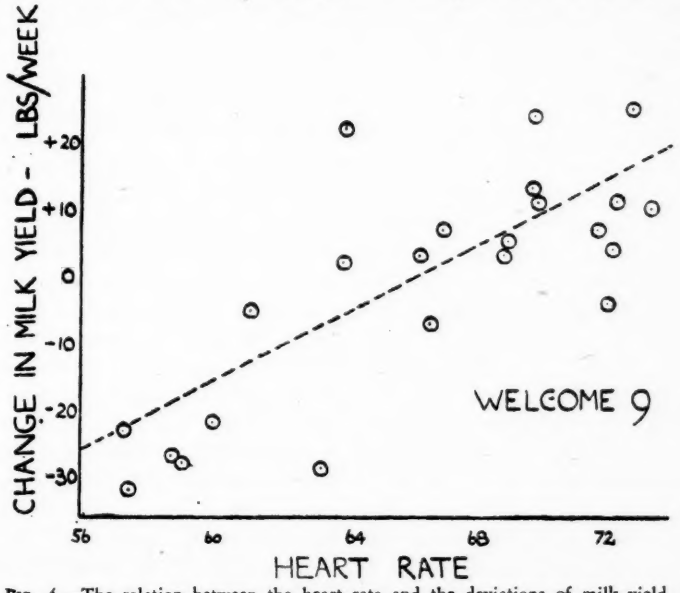

FIG. 4.—The relation between the heart rate and the deviations of milk yield from the normal decline.

difficulties, and in the case of the two cows where there are 4-5 months of unbroken records uncomplicated by the later stages of pregnancy, a straight line has been fitted to the weekly milk yields. The deviations from this straight line have then been correlated with the heart rates. This corrects the data for the normal decline of milk yields as lactation advances and although it is a simple method it is not to be recommended because the correlation coefficients so calcu-

lated are not always valid. The results for cow Welcome 9 are shown in Table 8 and graphically in Figure 4.

Both the correlation coefficients in Table 8 are statistically highly significant ($P<.01$). The regression coefficients of the last column show that an increase of 10 beats in the heart rate is associated with an increase in yield of $2\frac{1}{2}$ gallons of milk per week.

The data for the remaining two cows, Truth and Lily 7, are not amenable to this type of analysis, for there are not sufficient data to calculate an accurate rate of fall of milk yield, and large errors of interpretation could arise. Milk yields during these short periods have therefore been correlated directly with heart rates without correcting the former for the normal decline in lactation. Other cows which have been "controls" in experiments with iodinated proteins and thyroxine have also been used for this study. The rapid terminal phase of lactation has been excluded and the results are shown in Table 9.

TABLE 9

Direct correlation between heart rate and milk yield during short periods

Cow	*Period of lactation*	*No. of weeks of records*	*Correlation coefficient "r"*	*Regression coefficient "b"*
Linda 7	middle	8	+0.884	+2.28
Pearl 8	late	8	+0.976	+5.85
Flora 48	middle	8	+0.902	+1.80
Diana	middle	10	+0.772	+3.09
Lottie 13	late	10	+0.728	+1.85
Truth	early	10	+0.807	+4.03
Peach 22	middle	10	+0.226	+1.07
Lily 7	late	10	+0.943	+5.11
Truth	late	10	+0.887	+2.58
Mean		equivalent to 60	+0.845	+3.07

The mean correlation coefficient given at the base of Table 9 was calculated using Fisher's "z" transformation (Fisher, 1938); it was significant statistically ($P<0.01$), and it shows that 71 per cent. of the variation in the milk yields of these cows was associated with variation in their heart rates. The regression coefficients show that on the average an increase of 10 beats in the heart rate is associated with an increase of three gallons of milk per week.

It is of interest to compare this relationship of the heart rate and milk yield in normal cows with the effect of iodinated protein on the heart rate and milk yield of experimental cows. Thus, iodinated casein feeding has been shown to increase the heart rate by 20 beats per minute and milk yield by 47 lb. per week (Blaxter, 1943b). This corresponds with 2.35 lb. of milk per beat, which is well within the range of the comparable figures for individual cows shown in Table 9.

This relationship suggests that increases in the total metabolism of the cow—for the heart rate is an approximate index of the total, not the basal metabolism—result in increases in milk yield. The cause of the changes in the total metabolism of normal cows associated with lactation is, in all probability, nutritional. Although data on food consumption are available for the four cows, these are not sufficiently accurate to show food intake changes over long periods for it is only possible to make an estimate of the amount of grass eaten, and the exact amount of bulky food consumed cannot be accurately ascertained under normal conditions of herd management. A further complicating factor is the difficulty of measurement of the net energy values of all foods given.

To show that the food intake does affect the heart rate, a small experiment was carried out with 12 dairy cows, in which both milk yields and heart rates were recorded before and after increases and decreases in food consumption. In this experiment all food was weighed and a precise control of food intake attained. The results are given in Table 10.

TABLE 10

The effect of an increase or a decrease of 2.5 lb. of starch equivalent consumed per day on the heart rate and milk yield of dairy cows

Ration	*Change in Heart rate (beats per minute)*	*Milk yield (lb. per week)*
Normal +2.5 lb. starch equivalent per day ...	+4.9	+ 5.1
Normal	0.0	0.0
Normal —2.5 lb. starch equivalent per day ...	—7.1	—14.4
Significant difference P = .05	±6.66	±15.7

Table 10 shows that changes in food intake cause changes in milk yield and changes in the heart rate, and thus the relationship between the heart rate and milk production deduced from the observational data is a relationship between total metabolism and milk production, largely due to changes in food consumption. This is also shown by the results of Ritzman and Benedict (1924), who found that the heart rates of steers at submaintenance, maintenance and during fattening were 33, 44 and 78 respectively.

The correlation between the total lactation milk production of cows with their heart rates might therefore be expected to be positive, but this would be largely the result of the higher food consumption of the higher yielder. The interpretation of such data is made more difficult because, under the same conditions, it appears that the heart rate is 10 or more beats higher in younger cows than in older cows, regardless of their milk yield.

It is of considerable interest to note the very large differences in the heart rate of cows at different seasons of the year. General observations which have been made show that the heart rates of cows are very high during the early months of the spring, falling off as the pasture supply deteriorates and increasing with the autumn flush of grass. Throughout the winter, heart rates are much lower than the corresponding spring and autumn rates. Thus for 12 cows during the winter of 1942-3 the mean heart rate was 60.9 (432 observations), while for 12 comparable cows during the early summer of 1943 the mean rate was 67.8 (432 observations), the difference being statistically significant at odds of 80 : 1. It can be concluded therefore that the total metabolism of cows is very much lower during the winter months, the probable cause again being a nutritional one.

(d) *The relationship between environmental temperature and metabolism.* Owing to the effect of a changing plane of nutrition of the cow on the heart rate, the data collected on the four cows have not been used to show the relationship between the environmental temperature and the clinical data. Nevertheless it is of interest to note that very low respiration rates of 15-20 occurred during the cold months of January, whereas during the warm months of summer respiration rates were between 40 and 50 on occasions.

Data for four control cows used in an iodinated protein experiment for four weeks have, however, been used for this study. They were all Dairy Shorthorns and were kept on a constant ration throughout this period. The

heart rates, body temperatures and respiration rates for the four cows were averaged for each day, and these were then correlated with the average dry bulb temperature of the cowshed. The results are shown in Table 11.

TABLE 11

The relation between byre temperature and the mean heart rate, respiration rate and body temperature of four cows

Statistic		*Based on 25 morning records*	*Based on 25 evening records*
Correlation of heart rate with byre temperature ...		+0.6656	+ 0.6873
Correlation of respiration rate with byre temperature		+0.7979	+ 0.8502
Correlation of body temperature with byre temperature		+0.6662	+ 0.5241
Increase associated with a rise of 10 degrees F. in cowshed temperature	Heart rate per minute ...	+2.12	+ 5.78
	Respiration rate per minute ...	+6.21	+12.59
	Rectal temperature degrees F.	+0.145	+ 0.342
Range of byre temperature in degrees F.		45.5–62.5	48.0–67.8
Value of "r" to be significant in each case at P = .01		0.51	0.51

The large effect of environmental temperature on the respiration rate is especially notable, while higher environmental temperature also resulted in slightly higher heart rates and body temperatures. This is not in agreement with Regan and Richardson's (1938) results, who found that with Holstein, Jersey and Guernsey cattle, confined in an air-conditioned room, heart rates declined with increasing environmental temperature, while the increase in the rectal temperature was only apparent when the environmental temperature was 70 degrees F. The difference between the results of these observations and their experiments is difficult to find, and possibly there may be a breed difference, for the present animals, Shorthorns, have often been seen to sweat. This may indicate that in these cattle there is an increased blood flow to the skin as in the case of man, when body temperature rises.

The difference between the morning and evening results is an effect of the relationship between respiration rate and environmental temperature being curvelinear, as shown in Figure 4. When an exponential function is fitted to the data the following result is found:—

$$RR = 5.6_{e}^{+0.00605t}$$

Where RR = the respiration rate per minute
t = the temperature in degrees F.
e = the base of the natural logarithms.

From this equation it follows that an increase of 18 degrees F. (10 degrees C.) is associated with an increased respiratory frequency of nearly 100 per cent. Thus at 50 degrees F. the respiration rate is 27.4 and at 68 degrees F. it is 48.8. The constant 5.6 represents the respiration rate at 0 degrees F.; at 32 degrees F. it would be 15.4 per minute. This approximates to the Van't Hoff law for the influence of temperature on the speed of chemical reactions, and shows the importance of the respiration in the thermoregulation of the cow.

The large variation in the respiration rate due to environmental temperature is the most important cause of the high relative variability of the respiration rate when compared with the heart rate.

Discussion

The data which have been presented are observational data, and their interpretation is not so precise as the interpretation of experimental data, for adequate

control of all conditions is not possible. Nevertheless, it is clear that pregnancy causes considerable increases in the heart rate and body temperature of the cow, thus high temperatures and pulses in cows heavy in calf may have little diagnostic value. A similar increase in the basal heart rate in the pregnant woman has been described by Burwell *et al.* (1938). In their studies an increase in total cardiac output of over 50 per cent. was also found, while both basal heart rate and cardiac output fell following delivery to the normal values.

The effect of nutritional levels on both the heart rate and on lactation is

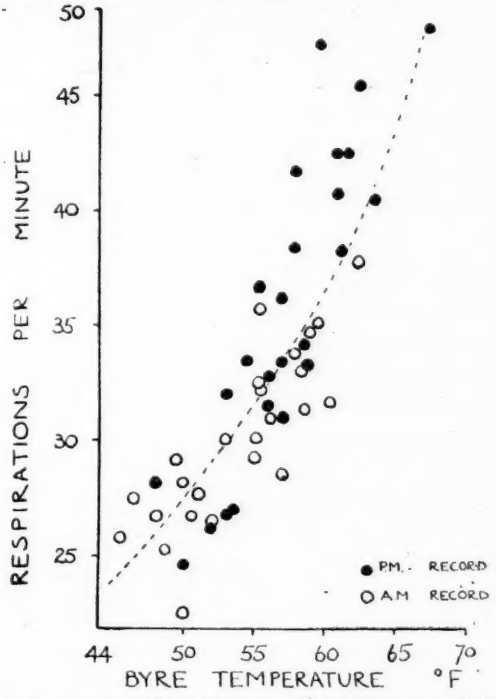

FIG. 5.—The relation between the respiration rate of the cow and the temperature of the environment.

of considerable interest, and in this connection it must be remembered the milk yield of the cow is dependent on both the amount of active mammary tissue present and its functional state. The general decline in yield with advance in lactation is then a result of a decline in the amount of active tissue present, while any factor, nutritional or endocrine, which results in an increased metabolism will cause an increase in the milk yield because of a heightened metabolism of the udder cells.

The solids-not-fats percentage of the milk shows a considerable normal variation under certain conditions (Bartlett, 1934), and it is of interest to compare the variation in the heart rate with the variation in the solids-not-fat percentage. First, both decline with increasing age of the cow; secondly, in the pregnant cow both the heart rate and the S.N.F. percentage rise when she is very late in lactation, whereas in the non-pregnant cow at a similar time no such change occurs; thirdly, under war-time conditions of feeding, a considerable

rise occurs in both when the cow is fed grass in the spring-time; and lastly, during the hot months of the summer both heart rates and solids-not-fat percentages fall. This suggests that the solids-not-fat percentage of the milk is determined by the total metabolism of the cow, and may indicate that a possible cause of milk of poor quality is a result of a lowered total metabolism. This is in accord with Rowland's suggestion that underfeeding is a cause of the low solids-not-fat percentages of milk under war-time conditions during winter (1944).

Summary

(1) A study has been made of some factors causing variation in the heart rates, respiration rates and body temperatures of dairy cows over long periods of time.

(2) The last 12 weeks of pregnancy are associated with increases of from 15-40 per cent. in the heart rate, slight changes in the respiration rate, and a rise of 0.75-1.25 degrees F. in the rectal temperature. There appears no change in any of the measurements associated with the first six months of pregnancy.

(3) Over short periods milk yield is positively and significantly correlated with resting heart rate ($r = 0.845$), and when records for longer periods are corrected for the normal decline in lactation deviations from the normal decline are again highly correlated with heart rate.

(4) The cause of this high correlation has been shown by experiment to be largely due to nutritional causes, and an increase of the heart rate by 10 beats is associated with a milk yield increase of between 2½ and 3 gallons per week in the normal cow.

(5) Heart rates are higher in the spring and autumn than in the winter and full summer. The reason is probably nutritional.

(6) The respiration rate of the dairy cow is very variable and increases nearly 100 per cent. for every rise of 10° C. in environmental temperature. Slight increases in heart rate and body temperature have also been found with increasing environmental temperature. These differ from those of other workers.

(7) The relation between the changes in heart rate under differing conditions of age, pregnancy, season of the year and nutritional plane appear associated with the known changes in the solids-not-fat percentage of the milk. This suggests a possible relationship between the total metabolism of the cow and the secretion of the solids-not-fat of the milk.

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